Ian Stone
Madison Fleming
Madeline Larkin

Summer 2017 Water Heating Results

Abstract

We present a method for heating water to pasteurization point using the sun's energy and practically available materials. We hope to implement this solar water heating method in Ugandan villages where we have previously worked with solar electric cookstoves to give the community members a renewable and cost-free option for heating bathing, sanitation, and drinking/eating water.

Background

During our group's research trip to Uganda during the Summer of 2016, we were exploring the need and potential design improvements for our Insulated Solar Electric Cookstove (ISEC). Due to the fact that over 4 million people die each year due to illnesses attributed to indoor cooking pollution, we see the opportunity to address this problem with photovoltaics as a timely one: the cost of photovoltaics has decreased by a factor of 300 since the 70s and continues to follow this pattern for the future. During our trip we implemented two ISEC stoves within village households. The women that used the ISECs most closely gave us the feedback that they began to use ISEC to heat water for bathing. After learning about this expressed need for heated bathing water, we wanted to explore a lower cost alternative for water heating that would negate the cost of PV.

The following graph demonstrates the common microbes that exist in water and the temperatures at which they are killed at.

Microbe	Killed rapidly at
Worms ,Giardia, Cryptosporidium, Entamoeba	55 °C
V. cholerae, E. coli, Shigella, Salmonella typhi, Rotavirus	60 °C
Hepatitis A	65 °C

This outlines the temperature goals for which we would like to our solar heaters to reach to provide pasteurized water.

Design

The basic design of our solar water heaters utilizes sunlight as the source of heat energy. We recognized the need for our solar water heaters to, firstly, capture the sunlight by allowing for minimal reflection and, secondly, retain heat within the water instead of convecting through the bottom.

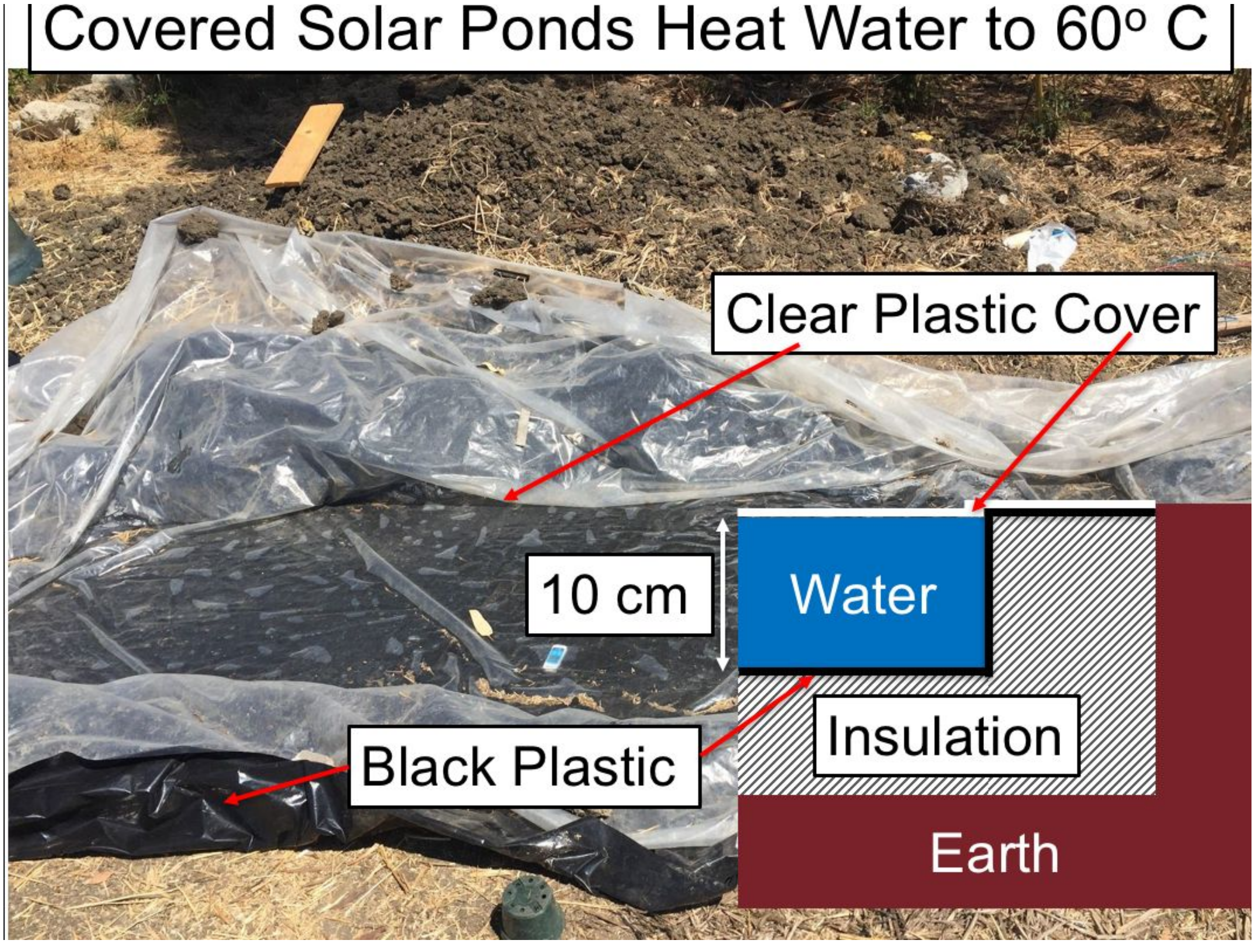
We gained insight from Dale Andreatta's paper "Solar Thermal Energy for the Village" to build our own ideas for what the design of our solar water heaters would entail.

First, we tried a teepee tarp design. To do this, we insulated the ground with hay and placed our water in a black container elevated above the hay. Then we placed a clear plastic covering over the entire thing, as to enclose most of the air and keep as much heat from escaping the enclosure. Our method utilizes a black tarp at the bottom to attract the sun while the clear plastic draped over will allow for the sunlight to enter and form a type of greenhouse effect. With our first design, we were able to get to a temperature of 60 °C, which would pasteurize water for drinking or pre-heating water to cook with. However this design didn't scale up well to heat larger quantities of water. When we became concerned about scaling, we realized that it may be best to try a pool-like design for the potential to heat larger quantities of water with less materials.

Pool Water Heaters

For the pool-style water heater, we began by digging three holes to dimensions of ~2.5'x1.5'x2'. We placed roughly a half-foot of hay insulation on all sides. We covered the holes with a black tarp then covered the tarp with clear plastic so the water would not seep through. We then filled each of the three holes to hold 6 cm of water. For one of the holes we put on layer of clear plastic over the surface of the water, we left one hole open to the air, and we covered the last hole with a layer of clear plastic and an extra layer of bubble wrap.

At this point we were technically limited by our lack of a thermal data logger. Therefore we manually recorded and monitored the temperature of the three experimental holes. Ultimately, the bubble wrap reached the hottest temperature of 60 °C around 3pm.



We then expanded the three holes into one large hole with the goal of heating a larger quantity of water. This pool-style heater follows the basic concept of attracting sunlight with a black plastic bottom and allowing sunlight to enter the system with clear plastic laid flat upon the surface of the water. We were able to obtain a water temperature of ~60 degrees for 60 gallons of water.

Conclusion

We believe that the large surface area of this pool-style design results in more uniform heat distribution of the water while absorbing more radiation from the sun. We hope to pursue this pool-style design for future implementation in Uganda. This simple water heating solution complements the work we do with ISECs quite nicely since both revolve around the advent of renewable, innovative, and simply methods/technologies for improving the health of the communities we work with.

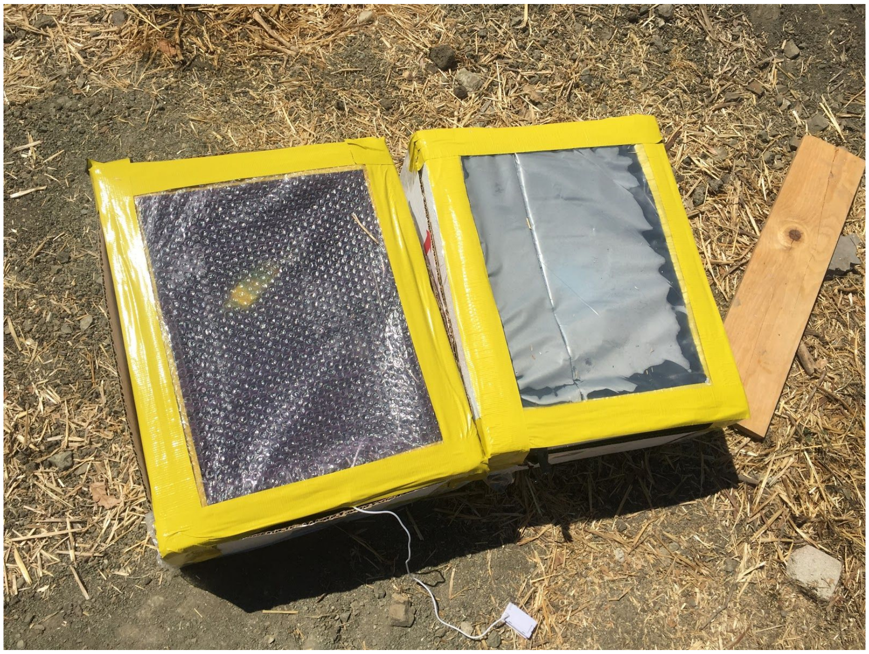
Appendix

Appendix A

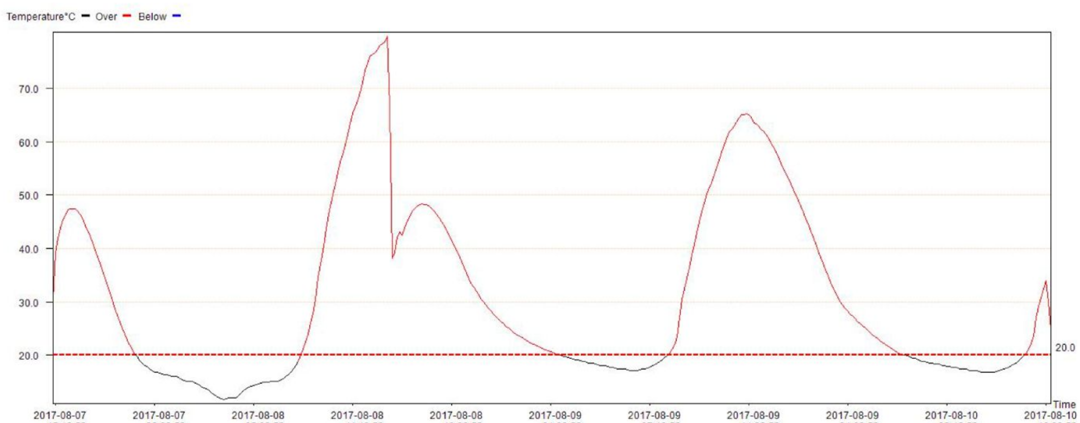
 

The above photos outline some other design iterations which failed. All designs follow the same basic foundation for capturing and retaining the sun's energy however the depth and surface area of the water for these design proved to be inadequate to heat large quantities of water.

Appendix B

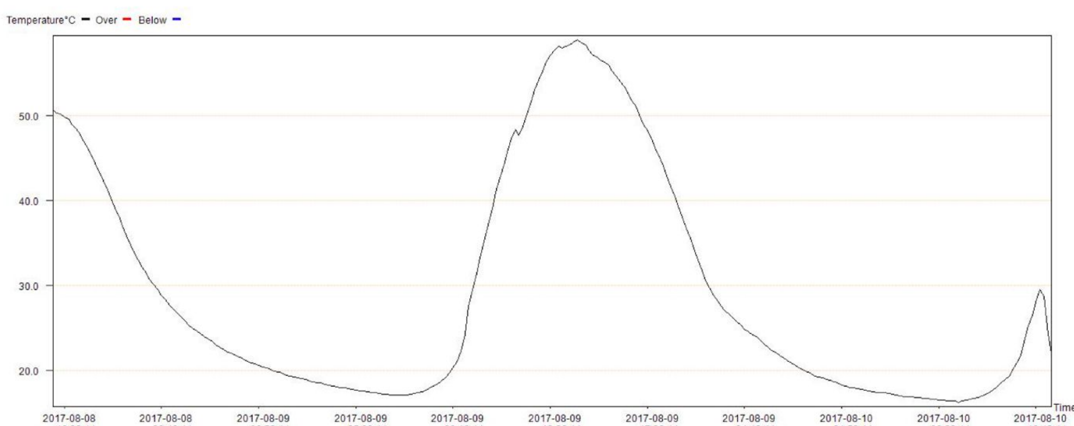


Note: On the left, Bubble Wrap top. On the right, clear plastic top.



Graph 1: Data from our water heater covered with **Bubble Wrap**

Note: The data is skewed because it was recording over a period of time when the water evaporated out which produced an inaccurate temperature reading. Therefore the only relevant data starts after the second peak. It looks like we got to about 65 C.



Graph 2: Data from our water heater covered with **4mm clear plastic**

The above figures are from a test that we did to see which water covering resulted in the least amount of reflection and a maximum amount of heat absorption in the water. After testing, bubble wrap seems to work best.

- Max for Plastic: 59 C
- Max for Bubble Wrap: ~65